Final Report

MONITORING THE EFFECTS OF HIGHWAY CONSTRUCTION IN THE SEDGEFIELD LAKES WATERSHED

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16. Abstract

This report summarizes the results of a water quality monitoring project to document the effects of the construction of the I40 bypass around Greensboro on the water quality of residential lakes in the Sedgefield and King's Mill communities. Automated monitoring equipment were installed at 4 locations downstream of the highway corridor in the drainage area to the Sedgefield lake, while in the King's Mill community, automated equipment was installed upstream and downstream of the corridor. At each monitoring site, discharge was monitored continuously and samples of stream discharge collected on a flow-proportional basis throughout the project. All samples were analyzed for total suspended solids (TSS), total solids, and turbidity, while selected samples were also analyzed for nitrogen and phosphorus forms. A recording raingage was also maintained for all of the monitoring period in the Sedgefield lakes watershed and in-situ measurements of temperature, dissolved oxygen, conductivity, and pH were made periodically at each site.

Monitoring data at all sites documented increases in sediment loading and turbidity following the start of highway construction, although to different extents. The greatest increase in sediment loading and turbidity occurred at the upstream site on the Tilly tributary. For this site, which was located just downstream of the highway corridor, about 60% of the sediment load during construction was associated with two tropical storm systems that occurred in September 2004. At this time the highway was particularly susceptible to erosion because more than 20 ft of fill had recently been added to bring the road surface to near grade and the sideslopes were not vegetated yet. Increases in sediment loading and turbidity at the other sites during highway construction were less severe and more like what would be expected. Mean turbidity levels during construction at all sites downstream of highway construction were greater than 50 ntu. Limited monitoring of temperature, specific conductance, DO, and pH for all six sites showed that highway construction had little, if any, effect on these parameters, except possibly temperature, which appeared to increase at Tilly-up and King's Mill-down, but this was not confirmed at the other sites. There was not enough samples analyzed for nitrogen and phosphorus to compare pre- to during-construction, but the data indicated that their levels in samples of stream discharge were sufficient to support nuisance aquatic growth in downstream lakes.

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DISCLAIMER

SUMMARY

This report summarizes the results of a monitoring project designed to document the effects of highway construction on the water quality of three unnamed tributaries in the Sedgefield Lakes and King's Mill residential areas. Two monitoring sites were installed on each tributary to continuously record discharge and collect flow-proportional samples. In Sedgefield, the upstream monitoring sites, Tilly-up and Ellery-up, were located just downstream of the highway corridor, while the downstream sites, Tilly-down and Ellery-down were located on the two tributaries just upstream of the Lake. For King's Mill, the sites were located just upstream (King's Mill-up) and downstream (King's Mill-down) of the highway corridor. All samples collected at the sites were analyzed for total suspended solids, total solids, and turbidity and selected samples were also analyzed for nitrogen and phosphorus forms. In situ measurements of temperature, specific conductance, dissolved oxygen (DO), and pH were made occasionally. A recording raingage was also maintained in the Sedgefield Lakes watershed.

Despite an array of erosion and sediment control measures installed on the highway corridor, sediment loss at the Tilly-up site increased from 0.01 to 7.6 ton/ac-yr with the start of highway construction, while average turbidity of samples went from 25 to 1,758 ntu. About 60% of the total sediment loss from the highway occurred during two tropical storm systems that hit the Greensboro area in September, 2004. While, the rainfall accumulation from these storms individually was less than a 2-year return period event, the effect of them occurring so close in time was to overwhelm the erosion and sediment control measures installed. Following these events, additional sediment basins, flocculation logs, and sediment traps were installed.

Sediment loss rate in the much large Tilly-down watershed increased from 0.07 ton/ac-yr prior to construction to 3.50 ton/ac-yr during the construction period. The much smaller increase was likely due to the fact that the highway corridor encompassed only 15.8% of the Tilly-down watershed. Mean turbidity levels in samples increased from 54 ntu pre-construction to 1,197 ntu during construction, which resulted in a corresponding increase in the turbidity of the lake.

Sediment loss rate at the Ellery-up site increased from 0.04 ton/ac-yr before construction to 2.02 ton/ac-yr during construction. This increase was less than half that of Tilly-up even though the highway corridor encompassed more than 25% of both drainage areas. The main difference was that construction in the Ellery-up area was at an earlier phase at the time of the tropical storms of September, 2004; thus, the highway corridor was less vulnerable to erosion.

At Ellery-down, the sediment loss rate increased from 0.20 ton/ac-yr before to 0.96 ton/ac-yr during the construction period. Mean turbidity levels in samples increased from 140 ntu before to 349 ntu. These increases can be attributed to a combination of the highway construction, the Hilltop Road widening, and residential construction upstream.

At King's Mill, sediment loss upstream highway corridor was 0.1 ton/ac-yr, while downstream it was 1.1 ton/ac-yr. Much of this increase could be attributed to the highway construction. Average turbidity of upstream samples was 43 ntu, while downstream it was 455 ntu.

Limited monitoring of temperature, specific conductance, DO, and pH for all six sites showed that highway construction had little, if any, effect on these parameters, except possibly temperature, which appeared to increase at Tilly-up and King's Mill-down, but this was not confirmed at the other sites. Similarly, the few samples analyzed for nitrogen and phosphorus showed levels sufficient to produce aquatic growth in downstream impoundments.

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INTRODUCTION

North Carolina has one of the strongest sediment and erosion control programs for construction sites in the U.S. in terms of its comprehensiveness, financing and staffing levels (Paterson et al., 1993). The program requires anyone who intends to disturb one acre or more of land to have an erosion and sediment control plan detailing the area to be disturbed and measures used to control sediment export from the site throughout the life of the project. Despite this ambitious program, sediment remains the primary pollutant affecting the quality of North Carolina's surface waters. Construction-related activities were cited by the state as a major source of degradation to lakes (NC DENR, 1992). Further, Burby et al. (1990) reported that one-third or more of urban construction sites in the state release sediment to neighboring property and nearby streams.

Sediment from urban areas received public notoriety in North Carolina in 1997 when a plume of red, muddy runoff, thought to be from construction sites, was photographed on its way down the Neuse River. Following this incident, the Governor called on the NC Department of Environment and Natural Resources (NC DENR) to begin stricter enforcement of erosion and sediment control regulations on construction sites. In addition, the Governor asked for a review of standards and needs for the erosion and sediment control program. One of the identified needs was to develop a better understanding of the limitations and efficiency of erosion and sediment control practices.

One of the few comprehensive field studies in NC on the limitations and efficiency of erosion and sediment control practices was conducted by Line and White (2001). Their study evaluated standard sediment traps on 2 residential construction sites over a nearly 2-yr. period of actual construction and rainfall activity. Results documented that 59 and 69% of incoming sediment from Piedmont and Coastal Plain construction sites was retained in the two traps. In addition, the study reported that 4.4 ton/ac-yr of sediment was exported from a Piedmont residential construction site in spite of and approved erosion and sediment control plan. This study underscores the difficulty of controlling sediment export from most construction sites.

The NC Department of Transportation manages its own erosion and sediment control program within its Roadside Environmental Unit. Erosion and sediment control plans are developed for every construction project and field personnel of the Roadside unit regularly inspect projects to ensure compliance with the provisions of the law. As stated in the above paragraph even when sites are following an approved erosion and sediment control plan some sediment may still leave a construction site and enter nearby waters. The effect of this sediment on the waters is dependent of the amount of sediment exported, the size and quality of the waters, and aquatic life in the waters. This study was designed to evaluate through water quality monitoring the effectiveness of the sediment control efforts on the I40 bypass in the Sedgefield Lakes and King's Mill communities.

METHODOLOGY AND PROCEDURES

Ideally evaluating the effects of construction in most watersheds would include a period (1.5-2 yr) of monitoring prior to the start of construction and then would continue through the completion of the project, which would be at least 3 years. The pre-construction monitoring is needed to adequately characterize the hydrology and sediment export of the area prior to disturbance and the rest of the monitoring data, during and hopefully some after construction, could be statistically compared to pre-construction to determine if significant changes had occurred. Two years of monitoring is recommended because climatic conditions affect discharge and sediment export to the extent that many different precipitation events are needed to make an adequate characterization. In some cases, monitoring an undisturbed drainage area upstream of the construction area can be substituted for pre-construction monitoring; however, this is generally risky because few areas are stable for very long.

The Sedgefield Lakes monitoring stations were located on two unnamed tributaries, which for simplicity during this project will be referred to as Tilly and Ellery (fig. 1). The Tilly tributary had two monitoring sites named Tilly-up and Tilly-down. The Tilly up site was located (N36’ 1.9”; W79’ 53.4”) just downstream of the highway corridor along a relatively stable and straight reach of an intermittent channel of the Tilly tributary. The site was moved about 50 ft downstream on 8/19/04 following the installation of a large culvert under the highway corridor, the outlet of which was downstream of the monitoring site. Moving the location of the site added very little to the drainage area; thus was insignificant with respect to runoff or sediment yield. The site was equipped with a 3 ft rectangular weir, an automated sampler with a pressure transducer flowmeter, and a tipping bucket raingage connected to the sampler (fig. 2). A standard weir equation was used to convert water stage measurement into discharge. Flow-proportional samples were collected based on the discharge measurements. Because the outlet from a stormwater detention pond was just downstream of the weir and the stream channel just downstream of the outlet had a rip-rap dam across it (left over from erosion and sediment control), the possibility of water backing up to the weir during high discharge from the pond was high. Hence, stones from the rip-rap dam were removed to facilitate the free flow of water down the channel.

The Tilly-down site was located just upstream of the lake (N36’ 2.0”; W79’ 53.6”) on the Tilly tributary (fig. 2). The channel was too wide and deep for a weir, so a staff gage was installed and a stage-discharge relationship developed for the site (fig. 3). This relationship was developed from several standard discharge measurements using a pygmy current meter and continuous depth and velocity measurements made with the automated sampler. The stage-discharge relationship was entered into an automated sampler thereby allowing it to convert its continuous stage measurements into discharge. Flow proportional samples were collected based on the discharge measurements.

The Ellery up site was located (N36’ 2.28”; W79’ 53.5”) just downstream of the highway corridor along a relatively stable and straight reach of an intermittent channel of the Ellery tributary. The site was equipped with a 2 ft rectangular weir, an automated sampler with a bubbler flowmeter (fig. 4). A standard weir equation was used to convert water stage measurement into discharge. Flow-proportional samples were collected based on the discharge measurements. The Ellery-down site was located just upstream of the lake (N36’ 2.18”; W79’ 53.6”) on the Ellery tributary (fig. 4). The channel was too wide for a weir, so a staff gage was installed and a stage-discharge relationship developed for the site (fig. 5.). This relationship was developed from several standard discharge measurements using a pygmy current meter. These measurements were supplemented with continuous depth and velocity measurements made during several storms with the automated sampler. The stage-discharge relationship was entered into an automated sampler thereby allowing it to convert its continuous stage measurements into discharge. Flow proportional samples were collected based on the discharge measurements.

The King's Mill monitoring stations, which will be referred to as KM-up (N36' 1.24"; W79' 52.35") and KM-down (N36' 1.19"; W79' 52.39"), were located on an unnamed tributary in the King's Mill residential area (fig. 6). The two monitoring stations were installed upstream and downstream of the highway corridor after the trees and houses had been removed (fig. 7). Thus, pre-construction hydrology could not be adequately characterized here either, but the drainage area to the upstream station had no highway construction in it, so it could serve as a background or a measure of pre-construction sediment yield for the area. A staff gage was installed at each station and a stage-discharge relationship was developed for each site (fig. 8). The relationship was developed from several discharge measurements made using the standard current meter and supplemented by continuous measurements of stage and velocity made by an area-velocity meter attached to the automated sampler during several storm events.

The drainage area to each monitoring station is shown in Table 1. The portion of each area encompassed by the highway corridor is also shown. For example, of the 18.6 acres draining to the Ellery-up monitoring site, 4.8 acres are the highway corridor. For King's Mill, the highway corridor is entirely contained within the area between the sites, which is why this area is subdivided and shown separately.

Table 1. Drainage Area to the Monitoring Stations.

Site	Drainage Area	Highway Corridor	
	ac	ac	%
Ellery-up	18.6	4.8	25.8
Ellery-down	147	24.1	16.4
Tilly-up	28.5	9.6	33.7
Tilly-down	132	20.9	15.8
King's Mill-up	96	0	0.0
King's Mill-down	183	21.2	11.6
Between KM-up & down	87	21.2	24.4

All 6 samplers were programmed to collect samples on a flow-proportional basis. The frequency of sampling was continually evaluated to insure that enough samples were collected to adequately characterize the water, while making sure the capacity of the sampler was adequate to sample all the discharge during the 2-week period before the sampler became full. An equal volume of sample was taken from each bottle that was collected during the 2-week monitoring period and placed in a laboratory container for analysis. All samples were analyzed for total suspended solids (TSS), total solids (TS), and turbidity. Selected samples will also be analyzed for total Kjeldahl nitrogen (TKN), nitrate nitrogen (NO_3-N), ammonia nitrogen (NH_3-N), and total phosphorus (TP) by the NC State University Biological and Agricultural Engineering Departmental laboratory. Samples were analyzed using standard methods (APHA, AWWA, WPCF. 1998). Selected samples were analyzed for TSS by two labs to assess the repeatability of the results.

In-situ monitoring of pH, dissolved oxygen (DO), conductivity, and temperature was conducted using a YSI multi-parameter meter. Due to various equipment repairs and low flow conditions, some of the planned measurements were not conducted. The meter was calibrated before each use. Typically the probe was placed in an area of flowing water near the sampling point and allowed to equilibrate before the readings were made. At each site the probe settled to or near the bottom of the column of water.

Effective quality assurance and control procedures are essential to ensure the utility of monitoring data (U.S. DOT, 1996). Due to the remote locations of the monitoring sites refrigeration was not feasible; however, the four samples analyzed for nitrogen and phosphorus were collected during periods of relatively cool temperatures. The biweekly samples were analyzed for TSS, TS, and turbidity only; hence, keeping the sample in the dark to minimize the growth of aquatic plants that increase turbidity was all that was needed to preserve the sample. The TSS was mostly made up of inert soil particles, which are rarely degraded by an extended period in water. All sampler tubing was new at installation and was not changed during the project, so no outside contamination was introduced into the samples.

RESULTS

This project had a unique partnership between the developer (NC DOT) and the residents of the Sedgefield Lakes community. Residents and NC DOT personnel met before any construction activity began in the watershed and continued to meet quarterly during the course of this project. Summaries of monitoring data were presented at the meetings and citizens' observations of runoff and sediment movement were voiced. A willingness to address citizens' concerns led to increased cooperation by all parties. Standard erosion and sediment control measures such as sediment traps, silt fence, and check dams were installed throughout the highway corridor; however, at least partly as a result of citizens concerns, additional erosion and sediment control measures were installed in the Tilly-up drainage area following the tropical storms of September, 2004. These included skimmer basins with baffles, flocculation logs, and accelerated seeding and mulching. Further, a special provision for accelerated seeding and mulching was implemented for most of the highway corridor in the watershed and turbidity curtains were installed in the two lake inlets where the Tilly and Ellery streams entered the lake. As has been observed on many construction sites, the establishment of vegetation limits widespread erosion, which is why seeding and mulching is critical. Also, NC DOT personnel inspected the corridor after every storm of greater than 0.25 inches and brought any problems encountered to the attention of their contractor(s).

Monitoring results are presented by site in the following section. The extent, general topography, and land use of the drainage area to the monitoring stations were determined from maps and observation. Activities, construction phase, sediment control practices, and other hydrologic factors occurring on the construction sites were recorded when observed during the biweekly visits to the monitoring sites.

Tilly-up Site

A summary of monitoring data for the Tilly-up site are in Table 2. The data are separated into pre- and post-construction periods. The pre-construction period ended about the time when clearing and grubbing were starting in the highway corridor. The pre-construction period was relatively short (0.38 years) and did not include any large storm events (see data in Appendix); therefore, the sediment load and hydrology could not be fully characterized, but relatively low runoff and sediment export was indicated by the limited data. The during-construction period started at this time and continued through the grading phase until 6/22/06. The rainfall, runoff, and TSS load (columns 4-6) were summed for each period, while the TSS concentrations and turbidity of samples (columns 7 and 8) were averaged. The pre-construction period sediment loss was 0.01 ton/ac-yr, while the during-construction sediment loss (TSS) was 7.6 ton/ac-yr. Obviously, the sediment loss increased considerably during the construction period. This increase can almost totally be attributed to the highway construction as the rest of the drainage area appeared to remained stable. Mean sediment (TSS) concentrations and turbidity of samples also increased (columns 7 and 8). Much of the increase in sediment loss could be attributed to erosion during two tropical storms in September of 2004 when about 60% of the total sediment loss from the drainage area occurred. While these storms were large, the total rainfall amount for each was less than the 2-year return period storm for the Greensboro area. However, the intensity of the 9/7/04 event did exceed the 2-year storm intensity. The fact that these events occurred within 2 weeks of each other made sediment and erosion control associated with them particularly difficult. The second storm system, while producing about the same amount of rainfall, resulted in more than twice as much sediment loss (see exhibit 1 in appendix). The probability of two tropical systems hitting an area in a three-week period is unknown, but is likely pretty low. During the following month, additional erosion and sediment control measures such as sediment basins and traps and slope stabilization matting (fig. 9) were installed in the drainage area to reduce erosion. Seed and mulch were also applied to the sideslopes of the fill areas so that by April, 2005 the slopes were well vegetated.

Table 3 contains temperature, conductivity, DO, and pH data measured in-situ during trips to the watershed. Because of the relatively small number of data points, making definitive statements about the data is not warranted; however, comparing the data with those collected from an urban stream draining a residential area of Charlotte, NC as reported by USGS (1999) could be useful. The specific conductance at the Tilly-up site was less than the Charlotte stream, while the temperature and pH were similar. The very small discharge of the stream could be subject to large changes in physical parameters as a result of only a small amount of stressor. The increase in temperature from pre- to during-construction possibly reflects clearing a significant portion of woods for the highway corridor or the fact that half the during-construction measurements were made during summer whereas none of the pre-construction measurements were made during summer.

Table 2. Summary of Rain, Runoff, and Sediment Data for the Tilly-up Site.

Begin	End	Dur. yr	Rain in	Runoff gal	TSS kg	TSS mg/L	TS mg/L	Turb ntu
Pre-Construction								
2/5/04	6/23/04	0.38	9.26	1,005,000	141	33	133	25
Sed loss= 0.01 ton/ac-yr								
During-Construction								
6/24/04	6/22/06	1.95	69.70	29,853,200	382,710	2,077	3,534	1,758
Sed loss= 7.6 ton/ac-yr								

Table 3. Summary of Physical Monitoring Data for the Tilly-up Site.

Begin	End	Count	Temp C	Cond[1]	DO mg/L	pH
Pre-Construction						
2/5/04	6/23/04	2	15.8	0.15	10.3	7.4
During-Construction						
6/24/04	6/22/06	8	18.3	0.14	5.9	6.6
USGS (1999)[2]			15.2	0.64		6.8

[1] Specific conductance with units of milliS/cm
[2] Study of residential urban stream in Charlotte, NC

Tilly-down Site

A summary of monitoring data for the Tilly-down station is shown in Table 4. Like the Tilly-up station, sediment loss increased, although not as much as at Tilly-up, in the during-construction period. The less dramatic increase could be attributed to the fact that a smaller portion of the drainage area to Tilly-down was disturbed by the highway construction. Construction of a residential subdivision in the upper part of the drainage area likely added sediment to the site during 2005. The average TSS concentration and turbidity of samples also increased during the construction period.

Table 5 contains temperature, conductivity, DO, and pH data measured in-situ during trips to the watershed. Like Tilly-up, the specific conductance is less than the Charlotte stream (USGS, 1999), while the temperature and pH are similar. The increase in temperature from pre- to during-construction possibly reflects clearing a significant portion of woods for the highway corridor or the fact that half the during-construction measurements were made during summer whereas none of the pre-construction measurements were made during summer.

Table 4. Summary of Monitoring Data for the Tilly-down Station.

Begin	End	Dur. yr	Rain in	Runoff gal	TSS kg	TSS mg/L	TS mg/L	Turb ntu
Pre-Construction								
2/5/04	6/23/04	0.38	9.26	18,057,000	3,400	58	207	54
Sed loss= 0.07 ton/ac-yr								
During-Construction								
6/24/04	6/22/06	1.95	69.70	119,918,000	798,550	1,281	1,580	1,197
Sed loss= 3.5 ton/ac-yr								

Table 5. Summary of Physical Monitoring Data for the Tilly-down.

Begin	End	Count	Temp C	Cond	DO mg/L	pH
Pre-Construction						
2/5/04	6/23/04	2	15.2	0.23	8.0	7.4
During-Construction						
6/24/04	6/22/06	8	17.7	0.16	5.8	6.5

Three samples were analyzed for nutrients. The analyses were conducted when sample recovery and transport to the lab occurred within 48 hrs of most of the sample collection. This happened when a relatively large storm event occurred a day or two before the scheduled sample recovery. Data for the three samples are shown in Table 6. For nitrogen forms, TKN and NO_3-N increased from Tilly-up to Tilly-down indicating increased inputs of nitrogen. This is relatively common for streams flowing through residential areas. The levels of TKN at Tilly-down far exceed the level of 0.3 mg/L of organic nitrogen considered adequate for excessive aquatic growth. However, some of the TKN is likely unavailable to aquatic plants. The mean TP concentration also increases slightly from Tilly-up to Tilly-down. The TP concentrations are considerably greater than what is generally thought to support excessive aquatic growth. At least some of this high TP concentration may be the result of excess sediment in runoff. Phosphorus is often attached to soil particles; hence, when the soil is eroded and becomes sediment in the runoff, phosphorus is carried along with it. If the eroded soil has high phosphorus levels, then relatively high levels of phosphorus will be in the stream discharge.

Table 6. Nutrient and Sediment Concentration Data for Tilly Tributary.

	Tilly-up					Tilly-down				
Date	TKN mg/L	NH_3-N mg/L	NO_3-N mg/L	TP mg/L	TSS mg/L	TKN mg/L	NH_3-N mg/L	NO_3-N mg/L	TP mg/L	TSS mg/L
16-Nov-04	0.88	0.00	0.28	0.28	233	1.16	0.00	0.17	0.31	345
15-Apr-05	0.37	0.01	0.22	0.42	57	1.12	0.01	0.45	0.49	108
20-Oct-05	0.99	0.00	0.13	0.65	3341	1.51	0.00	0.26	0.61	1781
Mean	0.75	0.00	0.21	0.45	1210	1.26	0.00	0.29	0.47	745

Ellery-up Site

A summary of monitoring data for the Ellery-up station is shown in Table 7. The data are divided into a pre-construction period, which was prior to clearing and grubbing the highway corridor, and the during construction period, which included most of the construction of the highway. Sediment loss rate increased from 0.04 to 2.02 ton/ac-yr during the construction period. This increase was less than half that of Tilly-up even though the highway corridor encompassed more than 25% of both drainage areas. The main difference was that the addition of fill material associated with bringing the highway to grade in the Ellery-up drainage area had not yet occurred when the tropical storms of September, 2004 hit. Thus, the relatively steep roadbanks of unconsolidated soil material were not in place yet. The increase in sediment load at this site cannot totally be attributed to the highway construction as a small portion of the drainage area was disturbed for a development, but this was likely insignificant. The average TSS concentration and turbidity of samples also increased during the construction period.

Table 8 contains the mean temperature, conductivity, DO, and pH data measured in-situ during trips to the watershed. Like the Tilly sites, the specific conductance was less than the Charlotte site (Table 3) while the temperature and pH were similar. The small decrease in temperature from pre- to during-construction cannot be explained except by the fact that during the construction period more measurements were made during summer.

Table 7. Summary of Monitoring Data for the Ellery-up Station.

Begin	End	Dur. yr	Rain in	Runoff gal	TSS kg	TSS mg/L	TS mg/L	Turb ntu
Pre-Construction								
2/5/04	8/20/04	0.54	17.41	2,099,250	367	36	187	29
Sediment loss= 0.04 ton/ac-yr								
During-Construction								
8/21/04	6/22/06	1.71	56.60	9,822,000	58,350	1,989	2,405	1,053
Sediment loss= 2.02 ton/ac-yr								

Table 8. Summary of Physical Monitoring Data for the Ellery-up.

Begin	End	Count	Temp C	Cond	DO mg/L	pH
Pre-Construction						
2/5/04	8/20/04	2	16.7	0.18	3.2	7.2
During-Construction						
8/21/04	6/22/06	8	15.9	0.22	5.2	6.3

Ellery-down Site

A summary of monitoring data for the Ellery-down station is shown in Table 9. The data are divided into a pre-construction period, which was prior to clearing and grubbing the highway corridor, and the during construction period, which included most of the construction of the highway. The construction period also encompassed the widening of Hilltop Road and the construction of residential housing development just upstream of Hilltop Road. Sediment loss rate increased from 0.20 to 0.96 ton/ac-yr during the construction period. This increase cannot totally be attributed to the highway construction as a significant portion of the drainage area was disturbed residential development and Hilltop Road. The average TSS concentration and turbidity of samples also increased during the construction period.

Table 9. Summary of Monitoring Data for the Ellery-down Station.

Begin	End	Dur. yr	Rain in	Runoff gal	TSS kg	TSS mg/L	TS mg/L	Turb ntu
Pre-Construction								
2/5/04	8/20/04	0.54	17.41	22,512,000	14,520	172	362	140
Sed loss= 0.20 ton/ac-yr								
During-Construction								
8/21/04	6/22/06	1.71	56.60	67,332,000	218,960	548	767	432
Sed loss= 0.96 ton/ac-yr								

Table 10 contains the mean temperature, conductivity, DO, and pH data measured in-situ during trips to the watershed. Like the Tilly sites, the specific conductance was less than the Charlotte site (Table 3) while the pH was similar. The reason for the elevated temperature during the pre-construction period was unknown.

Table 10. Summary of Physical Monitoring Data for the Ellery-down.

Begin	End	Count	Temp C	Cond	DO mg/L	pH
Pre-Construction						
2/5/04	8/20/04	2	23.2	0.23	5.6	7.4
During-Construction						
8/21/04	6/22/06	8	16.9	0.20	6.1	6.6

Three samples were analyzed for nutrients at Ellery-up and only one at Ellery-down (Table 11). The lack of samples at Ellery-down was due to an equipment malfunction and a lack of discharge for the one storm. For nitrogen forms, TKN and NO_3-N increased from Ellery-up to Ellery-down indicating increased inputs of nitrogen. This is relatively common for streams flowing through residential areas. The levels of TKN at Ellery-down far exceed the level of 0.3 mg/L of organic nitrogen considered adequate for excessive aquatic growth. The TP concentrations are considerably greater than what is generally thought to support excessive aquatic growth.

Table 11. Nutrient and Sediment Concentration Data for Ellery Tributary.

	Ellery-up					Ellery-down				
Date	TKN mg/L	NH_3-N mg/L	NO_3-N mg/L	TP mg/L	TSS mg/L	TKN mg/L	NH_3-N mg/L	NO_3-N mg/L	TP mg/L	TSS mg/L
16-Nov-04	0.80	0.00	0.12	0.37	362	1.97	0.00	0.32	0.35	251
15-Apr-05	0.98	0.01	0.05	0.49	300	na	na	na	na	na
20-Oct-05	1.08	0.00	0.08	0.63	2368	na	na	na	na	na
Mean	0.95	0.00	0.08	0.50	1010	1.97	0.00	0.32	0.35	251

King's Mill-up and Down Sites

A summary of monitoring data for the King's Mill up and down sites is shown in Table 12. Rainfall for the two sites was recorded at the Tilly-up site, which was less than 2 miles away. Sediment load (column 6) was considerably greater at the dowstream site. Because there was little to no pre-construction monitoring data, it is unknown how much the downstream sediment load would have increased in the absence of the highway construction. However, if the upstream sediment loss rate of 0.10 ton/ac-yr was used to estimate the pre-construction sediment loss rate, then the increase in sediment load in the absence of highway construction would have been 8,760 kg. Subtracting this estimate from the downstream sediment load and dividing by the area of the highway corridor, yields an estimated sediment loss rate of 18.05 ton/ac-yr for the highway corridor alone. The average TSS concentration and turbidity of samples (columns 7 and 8) also increased considerably from upstream to downstream. The upstream turbidity was slightly less than the state receiving water standard of 50 ntu (NC DENR, 1997), while the downstream average was about 9 times greater than the standard.

Table 13 contains the mean temperature, conductivity, DO, and pH data measured in-situ during trips to King's Mill. Like the Sedgefield sites, the specific conductance was much less than the Charlotte site (Table 3) while the pH was similar. The increase in temperature was likely caused by a combination of factors including the use of a temporary channel, which was lined with black erosion control fabric, during the construction of the box culvert and the removal of all trees in the highway corridor.

Table 12. Summary of Monitoring Data for the King's Mill Sites.

Begin	End	Dur. yr	Rain in	Runoff gal	TSS kg	TSS mg/L	TS mg/L	Turb ntu
Upstream Site								
5-Jun-04	22-Jun-06	2.05	71.8	56,497,000	17,970	79	187	43
Sed loss= 0.10 ton/ac-yr								
Downstream Site								
5-Jun-04	22-Jun-06	2.05	71.8	161,707,100	373,100	692	842	455
Sed loss= 1.10 ton/ac-yr								

Table 13. Summary of Physical Monitoring Data for the King's Mill Sites.

Begin	End	Count	Temp C	Cond	DO mg/L	pH
Upstream Site						
5-Jun-04	22-Jun-06	9	17.4	0.20	5.5	6.8
Downstream Site						
5-Jun-04	22-Jun-06	9	19.2	0.22	6.5	7.4

Three samples from King's Mill down and two from the upstream site were analyzed for nutrients (Table 14). The missing sample from the upstream sight was due to a lack of discharge for the period ending on 18-Apr-06. The TKN decreased and NO_3-N increased from upstream to downstream, neither of which appeared to be significant changes. The levels of TKN at both sites far exceed the level of 0.3 mg/L of organic nitrogen considered adequate for excessive aquatic growth. The TP and TSS increased considerably from upstream to downstream. The increase in TP may be related to the increase in TSS as phosphorus is often attached to sediment. The TP concentration was considerably greater than the 0.05 mg/L considered adequate for algal and periphyton growth.

Table 14. Nutrient and Sediment Concentration Data for King's Mill Tributary.

Date	King's Mill-up					King's Mill-down				
	TKN mg/L	NH_3-N mg/L	NO_3-N mg/L	TP mg/L	TSS mg/L	TKN mg/L	NH_3-N mg/L	NO_3-N mg/L	TP mg/L	TSS mg/L
15-Apr-05	0.82	0.01	0.58	0.46	17	0.92	0.01	0.43	0.46	76
20-Oct-05	1.25	0.00	0.5	0.32	117	1.19	0.00	1.40	0.82	1596
18-Apr-06	na	na	na	na	na	0.62	0.00	0.42	0.51	295
Mean	1.04	0.00	0.54	0.39	67	0.91	0.00	0.75	0.60	656

SUMMARY CONCLUSIONS

Rainfall and discharge were monitored continuously for about two years at four sites in the Sedgefield Lake area and two sites in the King's Mill area. Flow proportional samples were collected at each site and analyzed for TSS, TS, and turbidity. Selected samples were also analyzed for TKN, NO_3-N, NH_3-N, and TP. In-situ measurements of temperature, conductance, pH, and DO were made at various times. Two of the Sedgefield Lakes monitoring sites, Tilly-up and Ellery-up, were just downstream of the highway and two of the sites, Tilly-down and Ellery-down, were near the downstream end of the tributaries just upstream of the Lake. The King's Mill sites were just upstream and downstream of the highway corridor on the unnamed tributary draining the King's Mill residential area.

Sediment loss rate at the Tilly-up site increased from 0.01 ton/ac-yr during the 4.6 month pre-construction period to 7.6 ton/ac-yr during the 2 years of highway construction. Average turbidity levels in samples increased from 25 ntu before highway construction to 1,758 ntu during construction. About 60% of the sediment loss from the highway occurred during two tropical storm systems that hit the Greensboro area in September, 2004. Additional sediment control measures were installed following these events, which seemed to reduce sediment loss from the area. Therefore, the data indicates that the highway construction caused a significant increase in sediment loss from the area and a corresponding increase in the turbidity of the runoff from the area. Much of this increase was the result of the two tropical storm systems of September, 2004. These data show that the erosion and sediment control effort was not able to adequately control sediment loss from back to back tropical systems. The probability of two such systems occurring so close together is unknown, but likely is pretty small.

Sediment loss rate in the much large Tilly-down watershed increased from 0.07 ton/ac-yr prior to construction to 3.50 ton/ac-yr during the construction period. The much smaller increase was likely due to the fact that the highway corridor encompassed only 15.8% of the Tilly-down watershed. Mean turbidity levels in samples increased from 54 ntu pre-construction to 1,197 ntu during construction. This increase in the turbidity of incoming water caused a corresponding increase in the turbidity of the lake.

Sediment loss rate at the Ellery-up site increased from 0.04 ton/ac-yr before construction to 2.11 ton/ac-yr during construction. This increase was less than half that of Tilly-up even though the highway corridor encompassed more than 25% of both drainage areas. The main difference was that construction in the Ellery-up area was at an earlier phase during the tropical storms of September, 2004; thus, the corridor was less vulnerable to erosion.

At Ellery-down, the sediment loss rate increased from 0.2 ton/ac-yr before to 0.96 ton/ac-yr during the construction period. Mean turbidity levels in samples increased from 140 ntu before to 349 ntu during construction. These increases can be attributed to a combination of the highway construction, the Hilltop Road widening, and residential construction upstream.

At King's Mill, sediment loss upstream highway corridor was 0.1 ton/ac-yr, while downstream it was 1.1 ton/ac-yr. Much of this increase could be attributed to the highway construction. Average turbidity of upstream samples was 43 ntu, while downstream it was 455 ntu.

Limited monitoring of temperature, specific conductance, DO, and pH for all six sites documented levels similar to or better than an urban stream in Charlotte, NC (USGS, 1999). The highway construction had little, if any, effect on these parameters, except possibly water temperature, which appeared to increase at Tilly-up and King's Mill-down, but this was not confirmed at the other sites. There was not enough samples analyzed for nitrogen and phosphorus to compare pre- to during-construction, but the data indicate that the levels of nitrogen and phosphorus in discharge were sufficient to support nuisance aquatic growth in downstream impoundments.

Interaction and cooperation between NC DOT and the residents of the area helped reduce sediment movement from the highway corridor. Area residents' observations of runoff and sediment helped NC DOT focus efforts on potential trouble spots; thereby leading to improved erosion and sediment control.

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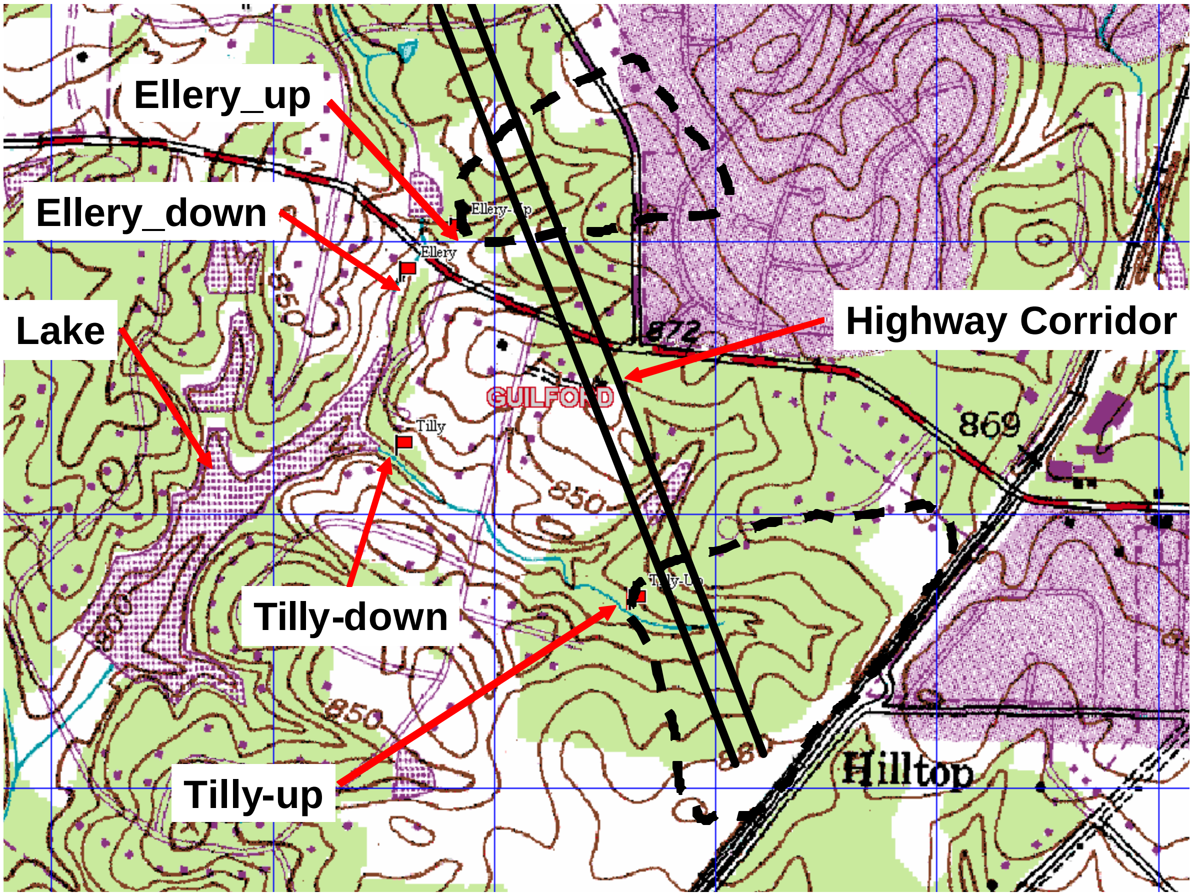

Figure 1. Sedgefield Lakes monitoring sites.

Figure 2. Tilly-up weir (left) and Tilly-down monitoring site (right).

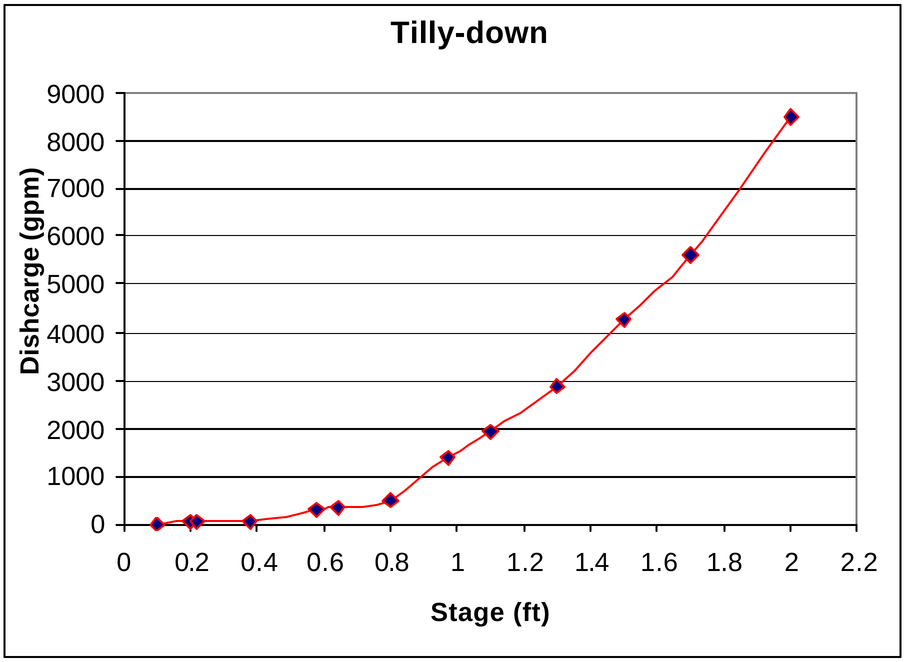

Figure 3. Tilly-down stage-discharge rating curve.

Figure 4. Ellery-up (left) and Ellery-down (right) monitoring sites.

Figure 5. Ellery-down stage-discharge rating curve.

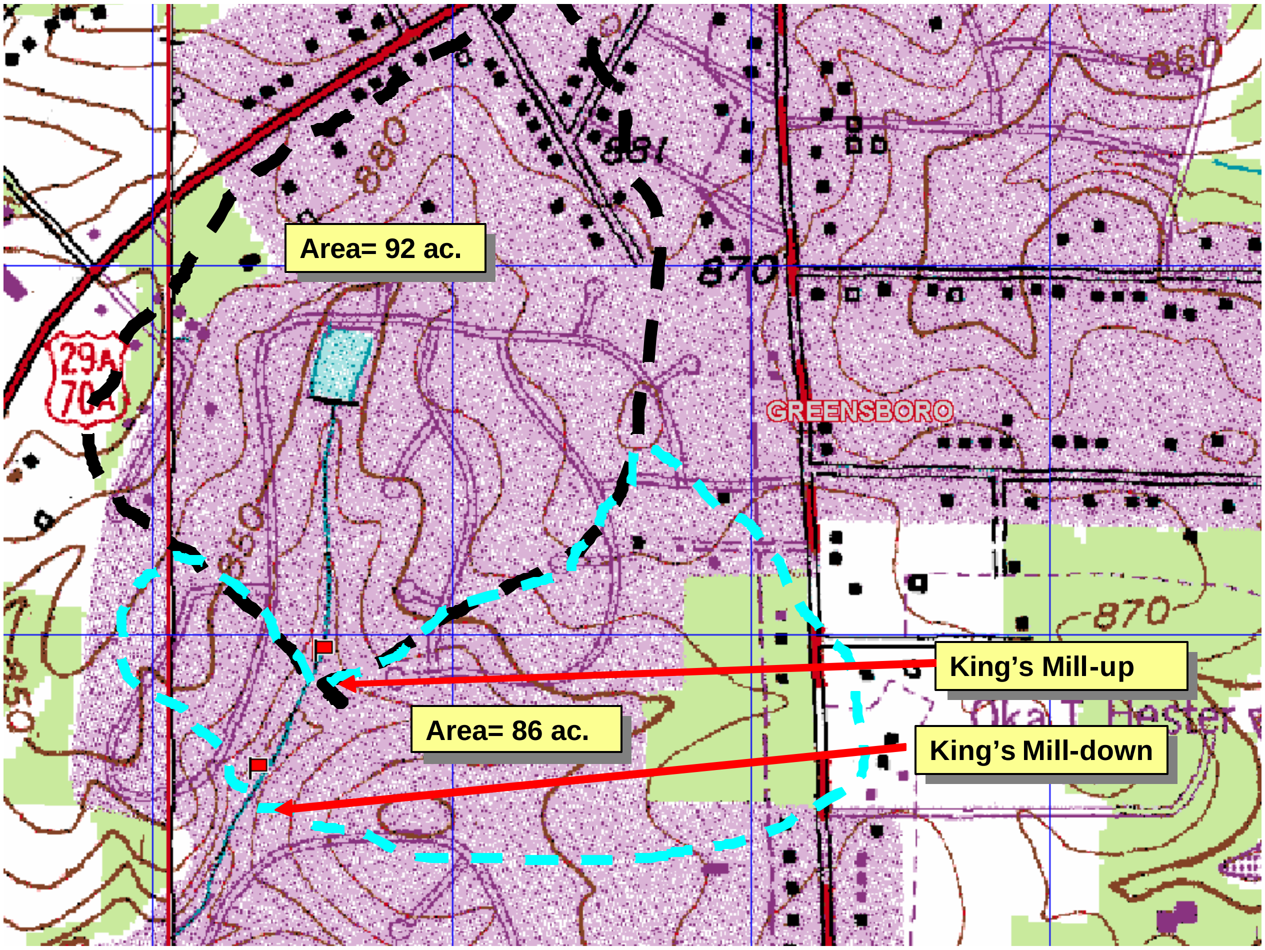

Figure 6. King's Mill monitoring sites.



Figure 7. King's Mill up (left) and down (right) monitoring sites.

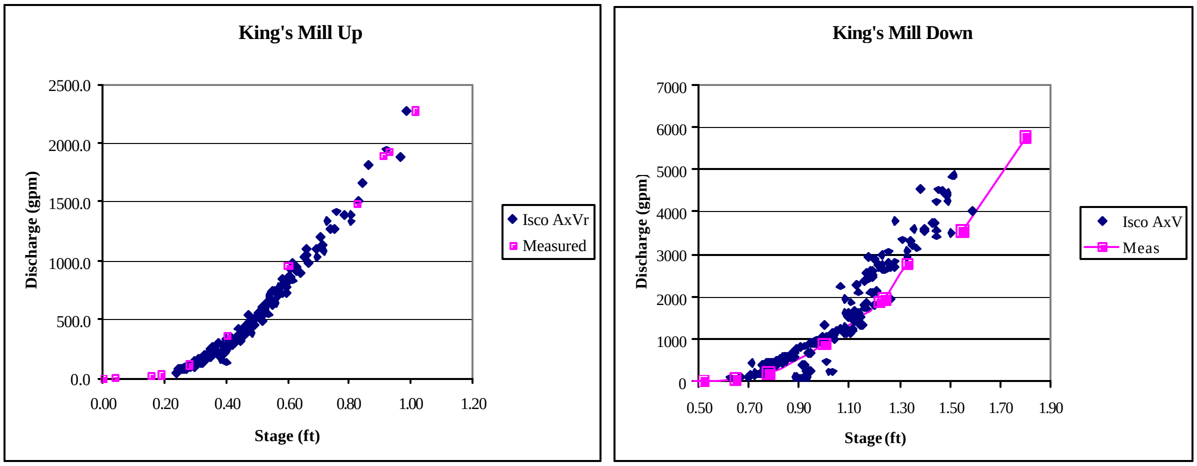

Figure 8. Stage-discharge rating curve for King's Mill up (left) and down (right) sites.

Figure 9. Additional sediment traps drainage area of Tilly-up.

The date shown is the day samples were collected; thus it represents the last day of the monitoring period. For example, the rainfall (0.75 in.) shown on row with 5-Feb-04 is the amount of rain occurring between 16-Jan-04 and 5-Feb-04.

Exhibit 1. Monitoring Data for the Tilly-up Site.

Date	Rain In	Discharge gal	TS mg/L	TSS mg/L	TS kg	TSS kg	Turb ntu	Temp C	Cond	DO mg/L	pH
5-Feb-04	0.75	166,002	190	52	119	33	9				
21-Feb-04	1.06	138,210	110	6	58	3	13				
29-Feb-04	0.31	68,489	100	7	26	2	14				
14-Mar-04	0.45	55,000	105	10	22	2	10				
21-Mar-04	0.55	11,330	85	15	4	1	12				
4-Apr-04	0.53	6,950	165	43	4	1	30	9.6	0.13	10.3	7.4
18-Apr-04	1.43	83,945	140	81	44	26	67				
30-Apr-04	0.25	65,000	135	23	33	6	17				
21-May-04	1.78	187,776	160	28	114	20	19				
4-Jun-04	0.68	54,996	136	38	28	8	na	22.1	0.17	NA	7.3
23-Jun-04	1.47	167,810	135	64	86	41	54				
9-Jul-04	1.88	135,623	1,010	712	518	365	457	27.5	0.16	7.6	na
19-Jul-04	2.30	308,382	17,772	17,570	20,743	20,508	6,963				
24-Jul-04	0.22	10,305	6,306	6,115	246	239	na				
6-Aug-04	2.10	82,174	16,250	14,780	5,054	4,597	9,550				
20-Aug-04	1.65	19,760	9,000	7,498	673	561	na	22.9	0.19	4.9	6.9
3-Sep-04	0.29	5,787	1,750	216	38	5	536				
9-Sep-04	4.25	1,022,000	17,376	na	67,215	67,215	10,000				
16-Sep-04	0.05	114,107	6,357	na	2,746	1,647	2,770				
29-Sep-04	4.39	2,838,588	15,260	na	163,954	163,954	8,740				
15-Oct-04	0.49	273,800	157	24	162	24	16				
31-Oct-04	0.42	86,400	257	94	84	31	91				
16-Nov-04	2.74	720,000	377	216	1,027	589	219				
20-Nov-04	0.02	61,000	147	43	34	10	56				
7-Dec-04	2.24	1,040,183	947	905	3,728	3,563	855				
29-Dec-04	2.45	1,327,317	420	240	2,110	1,206	259				
17-Jan-05	1.20	858,500	1,661	1,510	5,397	4,907	789	12.5	0.227	7.0	6.6
9-Feb-05	1.34	1,373,000	580	434	3,014	2,255	379	10.1	0.090	7.6	6.4
26-Feb-05	1.18	529,000	180	56	360	112	67				
16-Mar-05	1.78	1,144,000	1,217	1,048	5,270	4,538	860				
30-Mar-05	2.15	1,321,000	423	122	2,115	610	221				
14-Apr-05	1.74	738,000	140	115	391	321	55	14.3	0.093	4.4	7.2
6-May-05	0.71	1,171,000	187	40	829	177	16				
31-May-05	1.07	1,020,000	156	24	602	93	11				
20-Jun-05	1.76	632,000	197	77	470	184	72				
5-Jul-05	1.78	332,000	790	648	993	814	558	21.1	0.132	4.9	5.6
22-Jul-05	1.70	531,000	1,570	1,175	3,155	2,362	1142				
3-Aug-05	3.30	1,086,000	10,300	10,490	42,338	42,729	4870				
22-Aug-05	1.88	661,000	16,540	na	41,381	33,105	8120	21.7	0.132	5.0	na
13-Sep-05	0.37	177,500	1,910	1,740	1,283	1,169	990				
4-Oct-05	0.43	67,500	203	81	52	21	57				
20-Oct-05	2.44	424,760	3,468	3,090	5,576	4,968	2824				

6-Nov-05	0.21	285,690	283	119	306	129	87				
30-Nov-05	3.31	943,748	1,282	1,055	4,578	3,769	1140				
13-Dec-05	2.24	947,547	647	460	2,319	1,650	497				
24-Dec-05	1.20	951,780	293	199	1,057	716	179				
14-Jan-06	1.70	887,529	ns	na	1,025	765	na				
6-Feb-06	1.02	1,266,000	200	57	958	273	74				
25-Feb-06	0.90	721,444	na	na	549	156	na				
17-Mar-06	0.39	317,000	na	na	266	87	na				
11-Apr-06	1.36	342,900	na	na	391	192	na	16.7	0.135	na	6.7
6-May-06	2.10	625,700	500	331	1,184	783	291				
18-May-06	0.97	237,200	203	57	183	51	80				
22-Jun-06	3.98	2,215,000	1,523	1,343	12,771	11,258	1156				
5-Feb-04	0.75	166,002	190	52	119	33	9				
Ave.-pre			133	33			25	15.8	0.15	10.3	7.4
Ave.-post			3,534	2,077			1,758	18.3	0.14	5.9	6.6

*due to very high concentration of sediment only TS analysis was conducted, TSS was assumed to equal TS, which at these high levels has been shown to be a reasonable assumption.

Exhibit 2. Monitoring Data for the Tilly-down Site.

Date	Rain In	Discharge gal	TS mg/L	TSS mg/L	TS Kg	TSS kg	Turb ntu	Temp C	Cond	DO mg/L	pH
5-Feb-04	0.75	2,460,000	200	57	1,862	531	70				
21-Feb-04	1.06	6,245,000	155	19	3,664	449	28				
29-Feb-04	0.31	2,110,000	170	25	1,358	200	30				
14-Mar-04	0.45	1,128,000	150	21	640	90	17				
21-Mar-04	0.55	483,389	175	14	320	26	23				
4-Apr-04	0.53	190,084	225	30	162	22	24	9.9	0.203	10.5	7.5
18-Apr-04	1.43	4,341,000	248	110	4,067	1,807	98				
30-Apr-04	0.25	140,480	150	25	80	13	22				
21-May-04	1.78	271,700	220	51	226	52	42				
4-Jun-04	0.68	71,440	375	219	101	59	189	20.5	0.257	5.42	7.4
23-Jun-04	1.47	616,347	208	63	484	147	54				
9-Jul-04	1.88	1,451,000	2530	2236	13,895	12,280	2,130	24.3	0.188	4.46	na
19-Jul-04	2.30	2,428,000	9748	9090	89,584	83,537	6,280				
24-Jul-04	0.22	356,000	293	188	395	253	137				
6-Aug-04	2.10	1,515,000	3568	3347	20,460	19,193	2,019				
20-Aug-04	1.65	1,060,000	1027	828	4,120	3,322	620	22.2	0.2	7.8	6.8
3-Sep-04	0.29	626,000	210	54	498	128	78				
9-Sep-04	4.25	8,400,000	5389		171,322	171,322	10,000				
16-Sep-04	0.01	700,000				1,909					
29-Sep-04	4.39	9,335,000	7367	7367	260,286	260,286	6,640				
15-Oct-04	0.49	2,869,000	180	94	1,955	1,021	78				
31-Oct-04	0.42	674,798	1075	884	2,746	2,258	348				
16-Nov-04	2.74	4,230,000	517	332	8,277	5,316	293				
20-Nov-04	0.02	103,000	140	28	55	11	30				
7-Dec-04	2.24	6,908,000	330	198	8,628	5,177	184				
29-Dec-04	2.45	9,469,000	1380	1240	49,459	44,442	830				
17-Jan-05	1.20	4,724,000	600	428	10,728	7,653	266	12.8	0.196	7.7	5.8
9-Feb-05	1.34	5,141,000	369	225	7,171	4,378		10.1	0.130	7.0	6.6

26-Feb-05	1.18	2,000,000	155	40	1,173	303					
16-Mar-05	1.78	3,546,000	737	112	9,889	7,787	115				
30-Mar-05	2.15	5,845,000	150	58	3,318	1,283	80				
14-Apr-05	1.74	3,808,000	257	57	3,704	822	81	14.5	0.128	3.4	7.4
6-May-05	0.71	2,387,000	153	89	1,382	804	86				
31-May-05	1.07	1,860,000	ns	109		765					
20-Jun-05	1.76	919,000	333	180	1,159	626	154				
5-Jul-05	1.78	748,800	1860	1650	5,272	4,676	1,120	22.1	0.137	5.5	5.5
22-Jul-05	1.70	1,035,000	4787	4530	18,752	17,746	3,140				
3-Aug-05	3.30	2,980,000	6360	6450	71,736	72,751	2,970				
22-Aug-05	1.88	1,116,000	3007	2670	12,700	11,278	1,740	21.4	0.125	4.9	na
13-Sep-05	0.37	595,912	4353	4230	9,819	9,541	2,510				
4-Oct-05	0.43	104,000	640	440	252	173	309				
20-Oct-05	2.44	1,765,000	1873	1735	12,515	11,591	1,314				
6-Nov-05	0.21	339,200	188	42	242	54	45				
30-Nov-05	3.31	2,676,500	750	546	7,598	5,531	503				
13-Dec-05	2.24	5,943,900	362	236	8,137	5,315	228				
24-Dec-05	1.20	5,213,300	ns	na	na	4,251	na				
14-Jan-06	1.70	2,458,493	313	195	2,916	1,811	192				
6-Feb-06	1.02	2,367,000	222	85	1,986	765	88				
25-Feb-06	0.90	1,084,000	232	88	951	361	67				
17-Mar-06	0.39	838,400	270	134	857	425	82				
11-Apr-06	1.36	1,083,000	207	86	847	353	58	14.6	0.152	na	7.1
6-May-06	2.10	2,295,200	400	254	3,475	2,210	203				
18-May-06	0.97	522,900	172	62	340	123	70				
22-Jun-06	3.98	6,397,000	682	608	16,505	14,721	405				
Ave.-pre			207	58			54	15.2	0.23	8.0	7.4
Ave.-post			1,580	1,281			1,197	17.7	0.16	5.8	6.5

Exhibit 3. Monitoring Data for the Ellery-up Site.

Date	Rain in	Discharge gal	TS mg/L	TSS mg/L	TS kg	TSS kg	Turb ntu	Tem C	Cond	DO mg/L	pH
5-Feb-04	0.75	98,200	120	2	45	1	5				
21-Feb-04	1.06	129,000	240	24	117	12	28				
29-Feb-04	0.31	41,000	345	14	54	2	21				
14-Mar-04	0.45	158,470	170	5	102	3	14				
21-Mar-04	0.55	150,000	153	10	87	5	na				
4-Apr-04	0.53	173,395	135	14	89	9	13	8.2	0.18	7.2	7.4
18-Apr-04	1.43	190,500	280	172	202	124	101				
30-Apr-04	0.25	70,000	130	7	34	2	8				
21-May-04	1.78	157,000	120	10	71	6	12				
4-Jun-04	0.68	80,600	135	4	41	1	12	17.6	0.16	1.8	7.4
23-Jun-04	1.47	107,360	170	40	69	16	8				
9-Jul-04	1.88	142,620	197	58	106	31	52	20.4	0.18	1.7	na
19-Jul-04	2.30	182,240	184	49	127	34	na				
24-Jul-04	0.22	25,028	150	29	14	3	32				
6-Aug-04	2.10	239,229	220	102	199	92	59				
20-Aug-04	1.65	154,607	243	44	142	26	42	20.7	0.19	2.1	6.8
1-Sep-04	0.29	34,782	140	40	18	5	46				

9-Sep-04	4.25	529,000	7630	1025	15,277	2,052	2820				
16-Sep-04	0.01	30,800	760	400	89	47	235				
29-Sep-04	4.39	581,487	2367	2367	5,209	5,209	1005				
15-Oct-04	0.49	99,922	1400	1400	529	529	520				
31-Oct-04	0.42	28,467	280	34	30	4	32				
16-Nov-04	2.74	325,575	583	576	718	710	332				
20-Nov-04	0.02	26,532	226	18	23	2	11				
7-Dec-04	2.24	507,300	507	294	974	565	264				
29-Dec-04	2.45	510,500	1273	1055	2,460	2,039	822				
17-Jan-05	1.20	251,424	na	na	606	502	na	13.3	0.2	3.5	6.0
9-Feb-05	1.34	349,000	613	384	810	507	291	9.7	0.2	7.8	6.0
26-Feb-05	1.18	409,000	253	70	392	108	70				
16-Mar-05	1.78	572,000	663	440	1,435	953	385				
30-Mar-05	2.15	583,000	1070	900	2,361	1,986	618				
14-Apr-05	1.74	304,000	500	155	575	178	269	15.4	0.2	3.6	7.1
6-May-05	0.71	112,000	233	74	99	31	60				
31-May-05	1.07	272,000	276	95	284	98	58				
20-Jun-05	1.76	143,000	21973	21070	11,893	11,404	9720				
5-Jul-05	1.78	106,000	na	na	na	6,399	na	20.0	0.3	5.8	5.7
22-Jul-05	1.70	32,000	11357	10830	1,376	1,312	5750				
3-Aug-05	3.30	294,000	8657	8560	9,633	9,525	1530				
22-Aug-05	1.88	123,200	10590	10040	4,938	4,682	3610	20.1	0.3	5.3	na
13-Sep-05	0.37	87,020	303	105	100	35	90				
4-Oct-05	0.43	96,333	1663	1480	606	540	976				
20-Oct-05	2.44	325,027	2438	2175	3,000	2,676	1998				
6-Nov-05	0.21	57,740	342	133	75	29	126				
30-Nov-05	3.31	590,000	388	192	867	429	170				
13-Dec-05	2.24	509,000	2353	1700	4,534	3,275	1950				
24-Dec-05	1.20	300,000	na	na	na	741	na				
14-Jan-06	1.70	341,600	567	288	733	372	296				
6-Feb-06	1.02	406,040	512	276	786	424	273				
25-Feb-06	0.90	241,742	230	77	210	71	72				
17-Mar-06	0.39	85,000	229	68	74	22	58				
11-Apr-06	1.36	273,000	190	33	196	34	38	16.7	0.1	na	6.7
6-May-06	2.10	284,500	945	790	1,018	851	615				
18-May-06	0.97	193,207	183	40	134	29	50				
22-Jun-06	3.98	638,540	2495	2413	6,030	5,833	1708				
Ave.-pre			187	36			29	16.7	0.18	3.2	7.2
Ave.-post			2,405	1,989			1,053	15.9	0.22	5.2	6.3

Exhibit 4. Monitoring Data for the Ellery-down Site.

Date	Rain in	Discharge Gal	TS mg/L	TSS mg/L	TS kg	TSS kg	Turb ntu	Temp C	Cond	DO mg/L	pH
5-Feb-04	0.75	1,965,000	270	16	2,008	119	9				
21-Feb-04	1.06	4,194,000	215	70	3,413	1,111	50				
29-Feb-04	0.31	1,140,500	230	34	993	147	NA				
14-Mar-04	0.45	3,211,000	205	16	2,491	194	20				

21-Mar-04	0.55	1,714,000	290	21	1,881	136	16				
4-Apr-04	0.53	971,932	305	102	1,122	375	61	9.6	0.29	7.9	7.9
18-Apr-04	1.43	1,746,640	258	106	1,702	697	70				
30-Apr-04	0.25	242,310	124	26	114	24	NA				
21-May-04	1.78	344,608	130	32	170	42	20				
4-Jun-04	0.68	271,471	185	14	190	14	26	27.7	0.13	5.9	7.4
23-Jun-04	1.47	464,878	225	88	396	155	76				
9-Jul-04	1.88	381,736	900	536	1,300	774	596	26.3	0.24	4.2	na
19-Jul-04	2.30	989,158	965	715	3,613	2,675	429				
24-Jul-04	0.22	187,033	383	234	271	166	176				
6-Aug-04	2.10	768,500	614	424	1,785	1,234					
20-Aug-04	1.65	284,263	493	324	530	349	275	29.3	0.2	4.6	6.8
1-Sep-04	0.29	158,121	420	264	251	158					
9-Sep-04	4.25	2,518,000	1,501	1194	14,301	11,380	890				
16-Sep-04	0.01	546,365	600	376	1,241	778	282				
29-Sep-04	4.39	3,657,997	1,952	1952	27,020	27,020	1095				
15-Oct-04	0.49	532,613	1,333	1333	2,687	2,687	548				
31-Oct-04	0.42	301,073	263	90	300	103	78				
16-Nov-04	2.74	1,426,136	450	236	2,429	1,274	229				
20-Nov-04	0.02	2,995,000	450	236	5,101	2,675	229				
7-Dec-04	2.24	576,000	240	40	523	87	75				
29-Dec-04	2.45	2,516,400	346	114	3,296	1,086	134				
17-Jan-05	1.20	4,627,000	697	487	12,207	8,529	450				
9-Feb-05	1.34	1,934,000	413	240	3,023	1,757	209	13.1	0.2	5.3	5.9
26-Feb-05	1.18	1,539,000	393	158	2,289	920	143	10.6	0.2	9.1	6.4
16-Mar-05	1.78	903,000	547	304	1,870	1,039	357				
30-Mar-05	2.15	4,120,000	773	596	12,054	9,294	397				
14-Apr-05	1.74	1,014,000	ns			1,366	NA	14.5	0.1	3.4	7.4
6-May-05	0.71	617,000	203	60	474	140	57				
31-May-05	1.07	344,000	ns			237	NA				
20-Jun-05	1.76	287,000	ns			7,867	na				
5-Jul-05	1.78	248,000	ns			7,548	na	25.4	0.2	5.9	6.3
22-Jul-05	1.70	368,000	363	204	506	284	139				
3-Aug-05	3.30	1,350,000	777	528	3,969	2,698	453				
22-Aug-05	1.88	618,000	2,183	1880	5,107	4,398	1050	23.0	0.3	6.6	na
13-Sep-05	0.37	253,000	993	730	951	699	745				
4-Oct-05	0.43	602,000				6,043					
20-Oct-05	2.44	1,409,000				14,144					
6-Nov-05	0.21	201,700				2,025					
30-Nov-05	3.31	3,016,000	2,033	1690	23,212	19,292	1402				
13-Dec-05	2.24	5,028,500	1,086	676	20,667	12,866	752				
24-Dec-05	1.20	3,117,400	530	259	6,254	3,052	297				
14-Jan-06	1.70	1,522,600	535	266	3,083	1,533	311				
6-Feb-06	1.02	1,145,400	448	144	1,944	624	202				
25-Feb-06	0.90	857,340	292	121	946	394	99				
17-Mar-06	0.39	543,000	292	77	599	158	81				
11-Apr-06	1.36	750,400	225	68	639	193	71	14.6	0.2	na	7.1
6-May-06	2.10	1,802,700	710	504	4,844	3,439	420				
18-May-06	0.97	486,400	315	135	580	248	139				
22-Jun-06	3.98	4,235,120	2,525	2082	40,476	33,371	1692				

Ave.-pre			362	172			140				
Ave.-post			767	548			432				

Exhibit 5. Monitoring Data for the King's Mill-up Site.

Date	Rain In	Discharge gal	TS mg/L	TSS mg/L	TS kg	TSS kg	Turb ntu	Temp C	Cond	DO mg/L	pH
5-Jun-04	0.68	457768	400	216	693	374	87	19.5	0.2	5.2	7.2
23-Jun-04	1.47	420240	315	236	501	375	93				
9-Jul-04	1.88	653,462	127	91	314	225	17	24.4	0.22	6.3	na
19-Jul-04	2.30	1,078,359	232	121	945	492	54				
24-Jul-04	0.22	168,921	120	43	77	27	43				
6-Aug-04	2.10	556,087	147	51	309	107	21				
20-Aug-04	1.65	273,144	147	45	152	47	29	21.7	0.23	5.6	7.5
1-Sep-04	0.29	106,854	133	81	54	33	47				
9-Sep-04	4.25	4,054,000	197	156	3,023	2,386	61				
16-Sep-04	0.01	241,820	187	22	171	20	38				
29-Sep-04	4.39	5,088,682	233	69	4,488	1,329	35				
15-Oct-04	0.49	1,662,000	157	24	984	148	16				
31-Oct-04	0.42	928,000	146	18	513	63	17				
20-Nov-04	2.74	2,583,996	210	53	2,054	518	29				
7-Dec-04	2.24	2,453,000	160	106	1,486	984	46				
29-Dec-04	2.45	3,425,000	173	91	2,243	1,180	48				
17-Jan-05	1.20	1,744,890	210	98	1,387	647	38	12.5	0.23	5.8	6.4
9-Feb-05	1.34	1,420,000			976	396		10.2	0.17	9.0	6.8
26-Feb-05	1.18	830,000	180	46	565	145	32				
16-Mar-05	1.78	2,067,000	173	55	1,353	430	42				
30-Mar-05	2.15	3,519,000	183	90	2,437	1,199	59				
14-Apr-05	1.74	1,233,000	143	23	667	107	18	12.1	0.17	3.9	7.1
6-May-05	0.71	729,000	143	27	395	75	18				
31-May-05	1.07	489,000	193	47	357	87	30				
20-Jun-05	1.76	660,000	220	116	550	290	59				
5-Jul-05	1.78	993,600	237	138	890	519	72	21.1	0.23	3.4	5.6
22-Jul-05	1.70	641,000	227	81	550	197	48				
3-Aug-05	3.30	1,405,000	150	95	798	505	50				
22-Aug-05	1.88	844,000	173	74	554	236	45	21.2	0.19	5.1	na
13-Sep-05	0.37	331,000	180	42	226	53	25				
4-Oct-05	0.43	106,000				33					
20-Oct-05	2.44	523,000	212	99	419	196	64				
6-Nov-05	0.21	110,000				34					
30-Nov-05	3.31	1,600,000				497					
13-Dec-05	2.24	2,846,000	142	52	1,526	560	41				
24-Dec-05	1.20	1,884,000	113	40	808	285	32				
14-Jan-06	1.70	1,109,000	193	65	812	273	65				
6-Feb-06	1.02	525,378	145	25	288	50	24				
25-Feb-06	0.90	410,270	138	13	215	20	17				
14-Mar-06	0.39	218,000	nes	86	252	71	na				
11-Apr-06	1.36	649,700	na	na	377	115	na	14.2	0.18	na	7.0
6-May-06	2.10	1,161,800	na	na	421	239	na				

18-May-06	0.97	738208	na	na	396	131	na				
22-Jun-06	3.98	2,155,000	245	152	1,998	1,240	75				
Ave			187	79			43	17.4	0.20	5.5	6.8

Exhibit 6. Monitoring Data for the King's Mill-down Site.

Date	Rain In	Discharge gal	TS mg/L	TSS mg/L	TS kg	TSS kg	Turb ntu	Temp C	Cond	DO mg/L	pH
5-Jun-04	0.68	1,202,280	250	178	1,138	810	84	21.4	0.22	5.0	7.2
23-Jun-04	1.47	506,750	340	200	652	384	112				
9-Jul-04	1.88	1,725,000	195	133	1,273	865	82	24.1	0.24	4.9	na
19-Jul-04	2.30	3,654,627	335	278	4,634	3,839	106				
24-Jul-04	0.22	182,140	143	78	99	54	71				
6-Aug-04	2.10	1,112,174	216	74	909	312					
20-Aug-04	1.65	1,390,950	167	74	879	390	54	23.5	0.21	5.2	7.6
1-Sep-04	0.29	269,583	210	104	214	106	82				
9-Sep-04	4.25	5,755,000	398	314	8,670	6,840	180				
16-Sep-04	0.01	682,000	177	45	456	116					
29-Sep-04	4.39	9,472,500	395	265	14,162	9,483	181				
15-Oct-04	0.49	1,717,000	180	94	1,170	611	78				
31-Oct-04	0.42	1,132,000	217	36	930	154	34				
20-Nov-04	2.74	3,952,000	233	87	3,485	1,301	82				
7-Dec-04	2.24	6,656,500	430	240	10,834	6,047	196				
29-Dec-04	2.45	7,334,000	750	510	20,819	14,157	446				
17-Jan-05	1.20	3,736,358	536	318	7,580	4,497	218	14.4	0.22	13.0	7.5
9-Feb-05	1.34	4,166,000	306	90	4,825	1,419	107	10.0	0.2	6.8	6.9
26-Feb-05	1.18	2,217,000	236	44	1,980	369	61				
16-Mar-05	1.78	6,372,000	407	196	9,816	4,727	184				
30-Mar-05	2.15	7,721,000	200	29	5,845	847	54				
14-Apr-05	1.74	2,519,000	223	81	2,126	772	86	14.0	0.1	4.7	7.9
6-May-05	0.71	1,709,000	203	68	1,313	440	55				
31-May-05	1.07	1,622,000	ns			457	na				
20-Jun-05	1.76	2,188,000	833	640	6,901	5,300	437				
5-Jul-05	1.78	2,070,000						23.2	0.3	6.5	7.4
22-Jul-05	1.70	1,876,000	5,113	4,660	36,308	33,089	2,170				
3-Aug-05	3.30	4,394,000	3,710	3,900	61,702	64,862	1,835				
22-Aug-05	1.88	2,721,000	3,923	3,570	40,406	36,767	1,860	26.9	0.3	6.0	na
13-Sep-05	0.37	1,040,000	2,657	2,310	10,458	9,093	1,450				
4-Oct-05	0.43	1,245,000	517	464	2,435	2,187	223				
20-Oct-05	2.44	3,051,000	1,718	2,105	19,843	24,309	1,110				
6-Nov-05	0.21	1,739,000	1,723	1,536	11,343	10,110	1,278				
30-Nov-05	3.31	7,950,800	2,448	2,225	73,680	66,959	1,816				
13-Dec-05	2.24	7,745,000	853	644	25,015	18,879	597				
24-Dec-05	1.20	5,144,000				8,976					
14-Jan-06	1.70	4,851,000	440	278	8,079	5,104	252				
6-Feb-06	1.02	2,614,700	297	82	2,936	812	121				
25-Feb-06	0.90	2,353,230				1,648					

14-Mar-06	0.39	1,492,600	552	424	3,117	2,395	261				
11-Apr-06	1.36	4,152,800	563	420	8,855	6,602	278	15.5	0.2	na	7.6
6-May-06	2.10	4,720,900	872	680	15,575	12,151	684				
18-May-06	0.97	1,431,000	423	288	2,293	1,560	216				
22-Jun-06	3.98	7,000,000	293	170	7,772	4,504	112				
Ave.			842	692			455	19.2	0.22	6.5	7.4